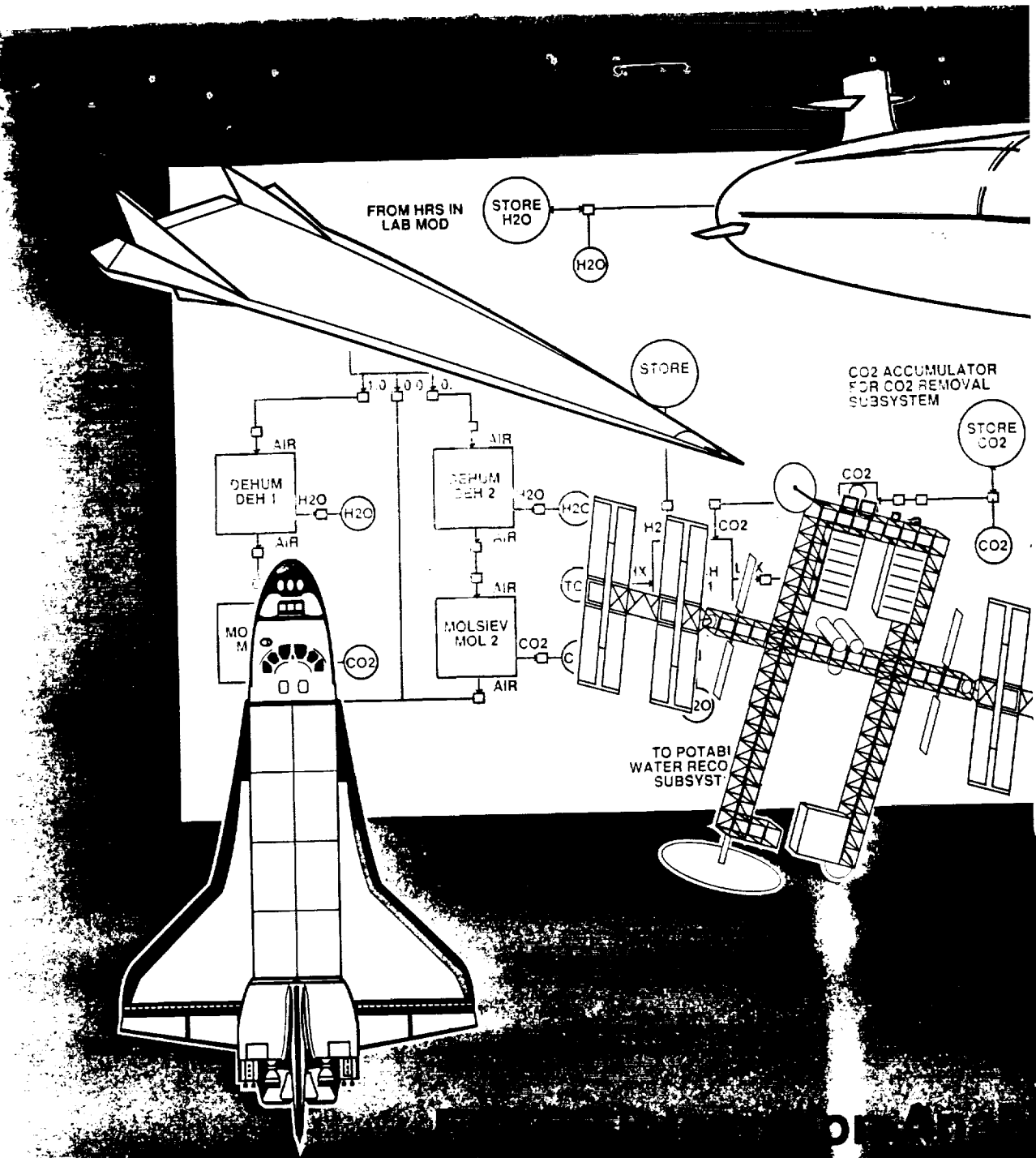

McDonnell Douglas Space Systems Company
Huntsville Division

MCDONNELL DOUGLAS

Space Station

ECLSS Integration Analysis

Contract NAS8-36407
Final Report

R C DaLee

R.C. DALEE, MANAGER
ECLSS INTEGRATION ANALYSIS

PREPARED FOR THE NASA MARSHALL SPACE FLIGHT CENTER UNDER CONTRACT NO. NAS8-36407,
EFFECTIVE DATE: 9 MAY 1985

McDonnell Douglas Space Systems Company - Huntsville Division
689 Discovery Drive, Huntsville, AL 35806

PREFACE

This McDonnell Douglas Report has been prepared by the Space Station ECLSS Integration Analysis Group of the Advanced Programs directorate of McDonnell Douglas Aerospace - Huntsville Division. This Final Report for Contract NAS8-36407 is prepared in accordance with Attachment J-2, Reports Requirements, of the contract Statement of Work.

TABLE OF CONTENTS

LIST OF TABLES

Section 1

INTRODUCTION

The Space Station Environmental Control and Life Support System (ECLSS) contract (NAS8-36407) with NASA MSFC covered the time frame from May 9, 1985 to December 31, 1992. The contract roughly covered the period of SSF development from early Phase B through Phase C/D Critical Design Review (CDR). During this time, McDonnell Douglas Aerospace (formerly McDonnell Douglas Space Systems Company) - Huntsville performed an analytical support role to MSFC for the development of analytical math models and engineering trade studies related to the design of the ECLSS for Space Station Freedom (SSF).

Section 2

CONTRACT TASKS AND RESULTING DOCUMENTATION

A complete narrative description of all tasks and subsequent results would require an extensive manpower effort. It is assumed that the requirements for final reporting, as stated in attachment J-2 of the Basic SOW, were intended to cover the original two year contract only, and not the entire seven year contract time frame resulting from extensions. In lieu of a complete narrative final report, MDA submits a comprehensive listing of ECLSS Integration Analysis tasks and resulting documentation delivered to NASA MSFC during the course of the contract.

A listing of contractual tasks by Work Breakdown Structure (WBS) is given in Table 2-1. Resulting documentation is summarized in Table 2-2. The documentation listing includes all contract deliverable documents (MDC reports), informal technical memorandums, conference technical papers, and subcontract final reports. The listing does not provide final task documentation in the form of presentations made to MSFC. Copies of all reports and presentations were distributed to MSFC personnel during the contract period of performance. In the event some data has been lost over the extended time frame of the contract, all reports and presentations generated on contract NAS8-36407 reside in permanent file at MDA-Huntsville, and will be made available at any time upon request from the Government. Requests can be made to the contract Technical Manager, R.C. DaLee, at (205) 922-7320.

Table 2-1. ECLSS Integration Analysis Tasks

WBS	TITLE	CONTRACT MOD	TASK ID
3.1	Data Gathering	Basic SOW	a
3.2	Model Development	Basic SOW	
3.2.1	Simplified General Cluster	Basic SOW	b, model 1
3.2.2	General Module Systems Model	Basic SOW	b, model 2
3.2.3	Cluster H2O Recovery	Basic SOW	c, model 5
3.2.4	Cluster O2 Recovery	Basic SOW	c, model 6
3.2.5	Cluster CO2 Removal	Basic SOW	c, model 7
3.2.6	Coolant Loop	Basic SOW	d,e, model 9
3.2.7	Body Mounted Radiator	Basic SOW	f, model 4
3.2.8	Cluster Equipment Cooling	Basic SOW	f, model 10
3.2.9	Air Temperature Control and Flow Distribution	Basic SOW	f, model 11
3.2.10	Cluster Consumables	Basic SOW	c, model 8
3.2.11	General Cluster Systems Model	Basic SOW	b, model 3
3.3	Hardware/Software System Support	Basic SOW	
3.3.1	Hardware Procurement	Basic SOW	g
3.4	Test Planning Support	5	h
3.5	General Test Support	5	i

Table 2-1. ECLSS Integration Analysis Tasks (Cont.)

WBS	TITLE	CONTRACT MOD	TASK ID
3.6	PMMS Support	7	j
3.7	U.S. Lab THC Analysis	7	k
3.8	Micro-Gravity Analysis	7	l
3.9	Atmosphere Revitalization Study	7	m
3.10	Transient Mass and Energy Potable and Hygiene Water Requirements	7	n
3.11	Metabolic Man Model	7	o
3.12	Thermal Transport Loop Study	7	p
3.13	Contaminant Data Base	7	q
3.14	CASE/A Programmer's Manual and User's Manual	10	r
3.15	CASE/A Pre-Release Verification	10	s
3.16	System Engineering Support	10	t
	PMMS Design and Test Continuation	10	u
3.17	CASE/A Enhancements	12	z
3.18	General Cluster Systems Model Update		Canceled per modifications to Supplemental Agreement 11.
3.19	ECLSS Automation Analysis	12	-
3.20	ECLSS Evolution Analysis	12	ff
3.21	CASE/A Documentation Update	13	aa
3.22	Timer Component	13	bb
3.23	O_2/N_2 Pressure Control Analysis	13	cc
3.24	CASE/A Conversion to EADS	13	dd
3.25	CASE/A Integrated Plot	13	ee
3.26	Sensor Environment Definition Study (Pathfinder)	14	gg
3.27	Real-Time Sensor Study (Pathfinder)	14	hh
3.28	Chemical Composition Monitoring Technology (Pathfinder)	14	ii
3.29	Feasibility Study for UV Promoted Oxidation Reactors (Pathfinder)	14	jj
3.30	Space Station ECLSS Task Plan	15	kk
3.31	ECLSS Design & Performance Analysis	15	ll
3.32	ECLSS Test Activities Support	15	mm

Table 2-1. ECLSS Integration Analysis Tasks (Cont.)

WBS	TITLE	CONTRACT MOD	TASK ID
3.33	Computational Hardware/Software	15	nn
3.34	Special Consultants	15	oo
3.35	Literature Survey	18	pp
3.36	Advanced Life Support Database Development	18	qq
3.37	Future Manned Mission Scenario	18	rr
3.38	Post ECLSS PDR Analytical Plan Development and Maintenance	20	ss
3.39	Post ECLSS PDR Design and Performance Analysis	20	tt
3.40	Post ECLSS PDR Test Activities Support	20	uu
3.41	Post ECLSS PDR Special Consultants	20	vv

Table 2-2. ECLSS Integration Analysis Documentation Delivered to MSFC.

Date	Document No.	Title	Author(s)
8/85	MDC W5040	Simplified General Cluster Systems Model ECLS System Assessment Program Enhancements	R.E. Ferguson
9/85	MDC W5055	Detailed Cluster Consumables Model	R.E. Ferguson
11/85	MDC W5059	Space Station Cluster Coolant Loop Model	R.E. Ferguson
11/85	MDC W5060	Space Station Detailed Cluster Loop Water Recovery Model	R.E. Ferguson
11/85	MDC W5061	Space Station Cluster Closed Loop Oxygen Recovery Models - Oxygen Generation	R.E. Ferguson
11/85	MDC W5062	Space Station Cluster Closed Loop Oxygen Recovery Models - Carbon Dioxide Reduction	R.E. Ferguson
12/85	MDC W5072	General Module Systems Model - G189A Version	R.E. Ferguson
12/85	MDC W5073	General Module Systems Model - CASE/A Version	R.E. Ferguson
2/86	MDC W5078	Space Station TRASYS Model for Body Mounted Radiator Study	R.E. Ferguson
2/86	MDC W5079	Space Station Body Mounted Radiator Model	R.E. Ferguson
5/86	MDC W5086	Space Station Cluster Detailed Carbon Dioxide Removal Model - Electrochemical Depolarizer Concentrator (EDC)	R.E. Ferguson
5/86	MDC W5087	Space Station Cluster Detailed Carbon Dioxide Removal Model - LiOH, Molecular Sieve, and Solid Amine	R.E. Ferguson
6/86	MDC W5089	Space Station Equipment Cooling Model	R.E. Ferguson
8/86	TM-ECLS-86001	Space Station Reference Configuration TRASYS Model	A.S. Bacskay
8/86	TM-ECLS-86002	Space Station Reference Configuration Passive Thermal Model	A.S. Bacskay
8/86	TM-ECLS-86003	Space Station Reference Configuration Active SINDA Models	A.S. Bacskay
10/86	MDC W5983	General Cluster Systems Model	R.E. Ferguson
11/86	MDC W5096	CASE/A Graphical Interface	R.E. Ferguson
3/87	MDC W5109-1	Bosch Carbon Reactor CO2 Reduction Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5110-1	Electrochemical Depolarized Cell CO2 Removal Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5111-1	Multifiltration Water Reclamation - Hygiene Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5112-1	Multifiltration Water Reclamation - Potable Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5113-1	Four-Bed Molecular Sieve CO2 Removal Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5114-1	Reverse Osmosis Water Reclamation - Hygiene Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5115-1	Reverse Osmosis Water Reclamation - Potable Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5116-1	Sabatier/Advanced Carbon Reactor CO2 Reduction Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5117-1	Solid Amine Water Desorbed CO2 Removal Subsystem Test Plan	R.E. Ferguson

Table 2-2. ECLSS Integration Analysis Documentation Delivered to MSFC (cont.).

Date	Document No.	Title	Author(s)
3/87	MDC W5118-1	Static Feed Electrolysis Oxygen Generation Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5119-1	Thermoelectric Integrated Membrane Evaporation Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5120-1	Vapor Compression Distillation Subsystem Test Plan	R.E. Ferguson
3/87	MDC W5123-1	Solid Polymer Electrolysis Oxygen Generation Subsystem Test Plan	R.E. Ferguson
7/87	SAE 871423	A Computer Aided Engineering Tool for ECLS Systems	M.E. Bangham J.L. Reuter
7/87	SAE 871428	Intermodule Ventilation Studies for the Space Station	R.G. Davis J.L. Reuter
3/88	TM-88001-ECLSS	CO2 Accumulator Study for the Atmosphere Revitalization Subsystem	T.C. Tripp
3/88	TM-88002-ECLSS	Metabolic Man Model for the Atmosphere Revitalization Subsystem	R.D. Stout
3/88	TM-88003-ECLSS	Water Recovery and Management System Mass Balance Study	B.H. Wilkes R.G. Davis
3/88	TM-88004-ECLSS	Thermal Transport Loop Control Concept Evaluation	R.C. DaLee
3/88	TM-88005-ECLSS	U.S. Laboratory Temperature and Humidity Control Model	S.D. Gilley
5/88	MDC W5074-3	Computer Aided System Engineering and Analysis (CASE/A) User's Manual - ECLSS Series	R.E. Ferguson
5/88	MDC W5146-2	Computer Aided System Engineering and Analysis (CASE/A) Programmer's Manual - ECLSS Series	R.E. Ferguson
5/88	MDC W5157	Refrigerant Properties Prediction Program User's Manual	R.E. Ferguson
11/88	MDC W5170	Verification Analysis of the Computer Aided System Engineering and Analysis (CASE/A) Molecular Sieve (MOLSIEV) Routine	R.E. Ferguson
3/89	MDC W5176	Verification Analysis of the CASE/A Static Feed Water Electrolysis (SFWE) Routine	R.E. Ferguson
5/89	MDC W5179	Verification Analysis of the CASE/A Anode Feed Solid Polymer Electrolysis (AFSPE) Component Routine	R.E. Ferguson
5/89	MDC W5180	Verification Analysis of the CASE/A Solid Amine Water Desorbed (SAWD) Component Routine	R.E. Ferguson
5/89	MDC W5181	Verification Analysis of the CASE/A Bosch CO2 Reduction Component Routine	R.E. Ferguson
5/89	MDC W5182	Verification Analysis of the CASE/A Sabatier (SABAT) CO2 Reduction Component Routine	R.E. Ferguson
5/89	MDC W5183	Verification Analysis of the CASE/A Molecular Sieve (MOLSIEV) and Desiccant Bed (DEFLOW) Component Routine	R.E. Ferguson
5/89	MDC W5184	Requirements Analysis of a Knowledge Base System (KBS) for the Space Station Environmental Control and Life Support System (ECLSS)	R.E. Ferguson

Table 2-2. ECLSS Integration Analysis Documentation Delivered to MSFC (cont.).

Date	Document No.	Title	Author(s)
5/89	MDC W5185	Fluid Consumable Requirements Analysis for the Space Station U.S. Laboratory (USL) Utilizing the Resource Allocation Program	R.E. Ferguson
6/89	-	Space Station ECLSS Evolution Study Report to MSFC	B.L. Diamant R.C. DaLee D.A. Till R.J. Cole
7/89	SAE 891483	Microgravity Sensitivities for Space Station ECLS Subsystems	M.E. Bangham T.W. Carroll W.R. Humphries
8/89	TM-ECLSS-89001	SINDA '85/FLUINT Model of the Proposed Centralized Avionics Air Loop for the Space Station U.S. Laboratory (USL) Model	R.C. DaLee
12/89	TM-ECLSS-89002	Error Analysis of the Space Station O2/N2 Control Subsystem	M.C. Waldrop
2/90	TM-ECLSS-90001	Space Station Atmosphere Control and Supply (ACS) O2/N2 Control Failure Modes and Effects Analysis (FMEA)	M.C. Waldrop
2/90	TM-ECLSS-90002	FMEA Comparison Between SSF Baseline and Orbiter ACS O2/N2 Control Systems	M.C. Waldrop
7/90	SAE 901210	Past and Present Environmental Control and Life Support Systems on Manned Spacecraft	B.L. Diamant W.R. Humphries
7/90	SAE 901214	Water Recovery and Management Test Support Modeling for Space Station Freedom	H. Mohamadinejad A.S. Bacskay
7/90	SAE 901267	Computer Aided System Engineering and Analysis (CASE/A) Modeling Package for ECLS Systems - An Overview	R.C. DaLee A.S. Bacskay J.C. Knox
8/90	TM-ECLSS-90003	Feasibility Study of Utilizing an Orbiter O2/N2 Control Scheme versus a Modified Orbiter Control Scheme for Space Station Freedom	M.C. Waldrop
10/90	MDC W5074-5	Computer Aided System Engineering and Analysis (CASE/A) User's Manual - ECLSS Series Version 4.1	R.C. DaLee
10/90	MDC W5146-4	Computer Aided System Engineering and Analysis (CASE/A) Programmer's Manual - ECLSS Series Version 4.1	R.C. DaLee
10/90	MDC W5658	Advanced ECLSS Subsystem and Instrumentation Technology Study for the Space Exploration Initiative	R.C. DaLee
12/90	TM-ECLSS-90004	SINDA '85/FLUINT Hydraulic Model of the Proposed Water Recovery and Management System for the Space Station Freedom Laboratory and Habitat Modules	C.E. Martin
3/91	TM-ECLSS-91002	CO2 Fire Suppressant Distribution System Modeling for Space Station Freedom	J.P. Gedcke H. Mohamadinejad
6/91	TM-ECLSS-91003	SINDA '85/FLUINT Model of the Post TURBO External Atmosphere Control System (ACS) Emergency Repressurization and HBC Operations for Space Station Freedom	M.C. Waldrop
6/91	TM-ECLSS-91004	Hydraulic Model of the Space Station Freedom Water Recovery and Management (WRM) Distribution System for the Permanently Manned Configuration (PMC)	C.E. Martin

Table 2-2. ECLSS Integration Analysis Documentation Delivered to MSFC (cont.).

Date	Document No.	Title	Author(s)
6/91	TM-ECLSS-91006	Pressure and Temperature Drops in the O2/N2 Lines of the External ACS	M.C. Waldrop
7/91	SAE 911358	ECLSS Instrumentation Technology Development for the Space Exploration Initiative	J. Bao, B.L. Diamant P. Wieland, W.R. Humphries
7/91	SAE 911414	Space Station Freedom ECLSS Design Configuration: A Post Restructure Update	A.S. Bacskay R.C. DaLee
7/91	SAE 911472	Hydraulic Model of the Proposed Water Recovery and Management System for Space Station Freedom	C.E. Martin A.S. Bacskay
7/91	SAE 911473	Computer Simulation of the CO2 Fire Suppressant Distribution System for Space Station Freedom	J.P. Gedcke H. Mohamadinejad M.Y. Gard
8/91	TM-ECLSS-91001	Space Station Freedom Node 2 and Cupola Temperature and Humidity Control Study	J.Bao D.E. Anderson
9/91	TM-ECLSS-91007	Emergency Node Ingress and Pressure Equalization Valve (PEV) Analyses	M.C. Waldrop
11/91	TM-ECLSS-91008	A SINDA '85/FLUINT Analysis of Positive and Negative Pressure on the Vent and Relief Assembly for Space Station Freedom	M.C. Waldrop
12/91	TM-ECLSS-91009	Use of a Lowered Initial Storage Pressure Within the Space Station Fire Suppression System Centralized Source Tank	J.P. Gedcke
11/91	TM-ECLSS-91010	Space Station Freedom Cabin Air Filter Performance Study	D.E. Anderson
12/91	TM-ECLSS-91011	Fire Suppressant CO2 Concentration Required for MTC 10.2 psia Operations	J.P. Gedcke
1/92	TM-ECLSS-92001	Verification of the CASE/A Condensing Heat Exchanger (CHX) Subroutine	S.L. Butler T.C. Lee
2/92	Report No. 67681	Spacecraft Trace Contaminanat Monitor (TCM) Evaluation of Concepts (subcontract to Arthur D. Little, Inc.)	I. Bodek (Arthur D. Little, Inc.)
3/92	TM-ECLSS-92002	Avionics/Cabin Air Exchange Rates Based on Spacelab Rack Leakage Data	J.P. Gedcke
4/92	TM-ECLSS-92003	CASE/A Operations Logic Code for the Space Station Freedom Condensing Heat Exchanger (CHX) Bypass Control Algorithm	J. Bao T.C. Lee
4/92	Final Subcontract Report	Development of a Mathematical Model to Evaluate the Operation of the Multifiltration Unit in the Space Station's Drinking Water Treatment System (subcontract to Michigan Tech University)	J.C. Crittenden D.W. Hand D.L. Perram J.S. Gierke (Michigan Tech Univ)
5/92	TM-ECLSS-92005	A Review of the White Sands Test Facility Extinguishant Evaluation Test Report	J.P. Gedcke
6/92	TM-ECLSS-92006	Advantages and Disadvantages of Distributed versus Centralized Air Sampling Pipe Smoke Detection Systems	J.P. Gedcke

Table 2-2. ECLSS Integration Analysis Documentation Delivered to MSFC (cont.).

Date	Document No.	Title	Author(s)
6/92	Final Subcontract Report	Kinetics of the Bosch Reaction (subcontract to Georgia Tech University)	P. Agrawal S. Vaidyaraman (Georgia Tech Univ)
8/92	TM-ECLSS-92007	Analysis of the Space Station Freedom Man Tended Capability (MTC) Centralized Carbon Dioxide Fire Suppression Subsystem Using the FLOW-NET Computer Program	J.P. Gedcke